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BIAS IN FALLOUT DATA FROM NUCLEAR SURFACE SHOT SMALL BOY
An Evaluation of Sample Perturbation by Sieve Sizing

by

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ABSTRACT

Evaluation of sample bias introduced by the mechanical sieving of Small Boy fallout samples for 10 minutes revealed the following: Up to 20 % of the mass and 30 % of the gamma-ray activity can be lost from the large-particle (>1400 μ) fraction. The pan fraction (<44 μ) can gain in weight by as much as 79 %, and in activity by as much as 44 %. The gamma-ray spectra of the fractions were not noticeably altered by the process. Examination of unbiased pan fractions (before mechanical sieving) indicated bimodality of the mass-size distribution in a sample collected 9,200 feet from ground zero, but not in a sample collected at 13,300 feet.

SUMMARY

Problem

The discovery of friable, fritted particles in Small Boy debris raised doubt atout the validity of results obtained after use of mechanical sieving for size separation.

Solution

The bias effect was evaluated by measurement of weights, gamma-ray spectra and gamma-ray activities of size fractions that had been separated by hand sieving, and by comparison of these results with similar data obtained by mechanical sieve separation of reconstituted samples.

INTRODUCTION

The development and testing of models for fallout formation and distribution rely heavily on data obtained from field tests. It is therefore important to seek out and evaluate sources of sample perturbation and data bias so that these sources, when found to be significant, can be eliminated.

A potential source of significant bias was reported in the examination of debris from Shot Small Boy[1] of Operation Sunbeam (Nevada Test Site). Small Boy was a low-yield shot fired from a wooden tower not far above a surface of alluvial silt in a dry lake bed. Although the particle size of the pre-shot silt was less than 44 microns, radioactive fallout particles were observed with diameters larger than 2000 μ.[2] As Fig. 1 shows, some of the large particles were smooth, glassy and spheroidal, indicating their formation by the complete coalescence of molten silt. Others were rough, friable and irregular masses of sintered silt. These had apparently been formed either by the agglomeration of partially molten silt or by scavenging of unmelted silt by a molten droplet. It was questionable whether the latter type of particle could withstand the severe mechanical sieving the samples received, prior to their receipt at NRDL, without significant abrasion.

This report describes the evaluation of this effect. At the time the evaluation was conducted, the samples were 20 months old.

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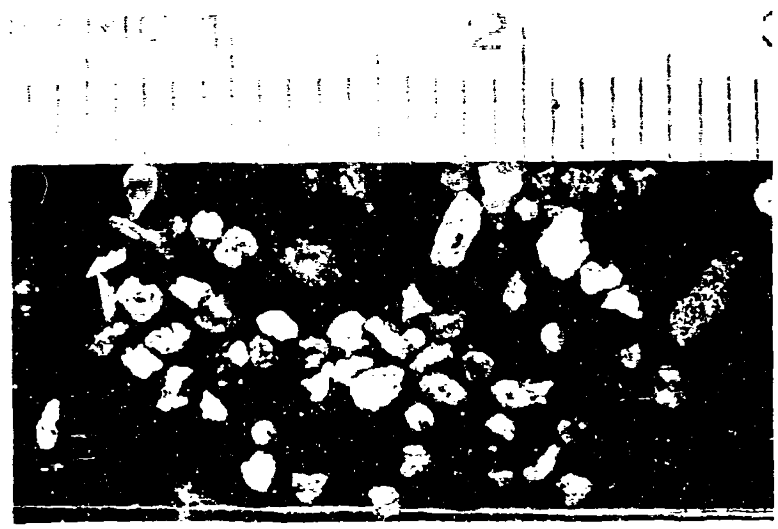

Fig. 1 Large Fallout Particles from Sample S2-PC-22 of Shot Small Boy. The scale numbers are in centimeters. A piece of gunny appears at the far right. Spherical, spheroidal and fritted particles are easily discernible.

EXPERIMENTAL

Two samples of local fallout were used for this study. Sample S2-PC-22 was collected 9,200 feet from ground zero and sample 305-AO-1 was collected at a distance of 13,300 feet. Both had been received in the original, unsieve· condition.

The assembly used for size separation consisted of seven 4-inch diameter Tyler Standard Screen Scale sieves together with cover and pan. Screen openings ranged from 44 to 2800 microns. Dry sieving was used. The first sieving was accomplished by gentle hand shaking inside a plastic gloved box. Each pan was shaken until it reached a constant weight (about 10 min.). After the sieving, the sieves were disassembled, and the contents of each sieve were transferred, with the aid of a funnel, to a pre-weighed screw-capped bottle. No particles were found on the 2800-micron sieve, but all the other sieves had retained particles. The size fractions were weighed, and assayed for gamma-ray activity with a well-crystal detector. Then gamma-ray spectra were obtained with a Technical Measurements Corporation 400-channel analyzer set at 2.5 kev per channel.

Samples of each pan fraction were mounted for particle-size counting by microscopic examination. First, a drop of cedar oil was placed at the center of a glass microscope slide. Then a fine spatula was used to transfer a small quantity of the dust onto the glass and the resulting mixture gently spread over a 1-inch square area of the slide with a flexible Teflon r . Care was taken that no agglomeration of dust particles occurred during the process. Counting was done through a 10X eye piece and a 43X objective lens. The smallest scale sub-division of the graticule under these conditions corresponded to 3.03 microns. The slides were scanned up and down, starting from the left to the right or vice versa until the whole square inch was completely scanned. 8,682 particles were measured for Sample S2-PC-22; 2,926 for Sample 305-AO-1.

The samples were next reconstiuted from the size fractions and returned to a reassembled nest of cleaned sieves. The nest was covered, and mounted on a Ro-tap machine for mechanical shaking. Sample S2-PC-22 was shaken for 10 minutes and Sample 305-AO-1 was shaken for 30 minutes.

Upon completion of the shaking operation, the nest was again disassembled and the weighing and counting operations were repeated. No decay corrections were necessary.

RESULTS AND DISCUSSION

Effect on Mass Distribution

Tables 1 and 2 compare the mass distributions before and after mechanical sieving for the two samples. In both instances losses occur in the first two or three fractions. It is noteworthy that a greater percentage of attrition was observed in the sample shaken for only 10 minutes than was observed in the sample shaken for 30 minutes. This may indicate that after 10 minutes, further abrasion is negligible. In each case a minimum loss is observed at the 175 to 350 micron fraction. This might simply mean that abrasion of particles of this size was compensated by addition of similarly sized particles formed by break-down in the coarser fractions. The 44 to 88 micron fractions and the 88 to 175 micron fractions again show losses for each sample. Finally, the pan fraction in each case shows the expected gain. In each case a few per cent of the total mass was lost. It is not known whether this loss is due to particles caught in the mesh or to the formation of a dust which was blown away. If the unrecovered mass belonged to a single particle size fraction it would have a pronounced effect on the gains indicated. In spite of the qualitative similarity between the results, there is a considerable lack of agreement in both the amount and per cent of net gain for any given fraction.

Effect on Activity Distribution

Tables 3 and 4 illustrate the effect of Ro-tapping on the distribution of gross gamma-ray activity with particle size. Except for the 175 to 350 and the 350 to 700 micron fractions, there is general correspondence between the gains of mass and activity in Sample S2-PC-22. On the other hand, the changes in gross gamma-ray activity distribution for sample 305-AO-1 correspond rather poorly with changes in the mass distribution for that sample. Again the sample shaken for the shorter time period shows the larger effect. Again also, the attribution of the departure from mass balance to a single fraction would have a pronounced effect.

TABLE 1

Effect on Mass Distribution for Sample S2-PC-22

	Weights (mg)			
Size Range (μ)	Hand Sieved	Ro-tapped (10 min)	Gain	Gain (%)
>1400	98.5	79.3	-19.2	-19.5
700-1400	177.8	157.7	-20.1	-11.3
350-700	386.5	391.0	4.5	1.2
175-350	51.7	56.6	4.9	9.5
88-175	99.1	84.3	-14.8	-14.9
44-88	246.5	231.1	-15.4	- 6.2
0-44	32.2	57.7	25.5	79.2
	1,092.3	1,057.7	-34.6	

TABLE 2

Effect on Mass Distribution for Sample 305-A0-1

	Weights (mg)			
Size Range (μ)	Hand Sieved	Ro-tapped (30 min)	Gain	Gain (%)
>1400	150.7	139.2	-11.5	- 7.6
700-1400	181.3	177.0	- 4.3	- 2.4
350-700	658.2	646.3	-11.9	- 1.8
175-350	194.9	194.9	0.0	0.0
88-175	159.2	158.2	- 1.0	- 0.6
44-88	147.4	137.7	- 9.7	- 6.6
0-44	54.6	68.7	14.1	25.8
	1,546.3	1,522.0	-24.3	

TABLE 3

Effect on Activity Distribution for Sample S2-PC-22

Size Range (μ)	Gamma-Ray Activity (10^5cpm) Hand Sieved	Ro-tapped	Gain	Gain (%)
>1400	9.04	5.64	-2.40	-29.8
700-1400	13.37	9.84	-3.53	-26.4
350-700	30.91	30.20	-0.71	- 2.3
175-350	3.78	3.59	-0.19	- 5.0
88-175	1.00	0.91	-0.09	- 9.0
44-88	0.54	0.48	-0.06	-11.1
0-44	0.09	0.13	0.04	44.4
	57.73	50.79	-6.94	

TABLE 4

Effect on Activity Distribution for Sample 305-A0-1

Size Range (μ)	Gamma-Ray Activity (10^5cpm) Hand Sieved	Ro-tapped	Gain	Gain (%)
>1400	1.11	0.97	-0.14	-12.6
700-1400	5.19	5.64	0.45	8.7
350-700	35.60	36.50	0.90	2.5
175-350	7.80	7.54	-0.26	- 3.3
88-175	2.96	2.97	0.01	0.3
44-88	1.78	1.67	-0.11	- 6.2
0-44	0.64	0.84	0.20	31.3
	55.08	56.13	1.05	

Effect on Gamma-Ray Spectra

It is well known that the smaller particles in fallout are richer in the volatilely behaving activities. It was therefore reasoned that the break-up of fritted particles might produce notable changes in the relative content of volatilely behaving and refractorily behaving activities in the small-particle fractions. Examination of the spectra before and after mechanical sieving indicated that this effect, if present, was too small to be observed.

Pan Fraction Analysis

Tables 5 and 6 list the numbers of particles found in different size ranges for the examined portions of the two pan fractions of the fallout samples. In each case the number of particles is extremely large in the range below 0.343 microns and only a few per cent of this number was found in the next larger fraction. This data gives the impression that the pan fractions consist almost entirely of sub-micron particles. However, if the frequency data is converted to weight data, the values listed as Nd^3 in the third column of each table are obtained, and these give quite the opposite impression. Although this third column lists simply the product of the number of particles with the cube of the diameter, this quantity is approximately equal to the weight of the sample from the pan fraction in picograms. The last column in each table gives the ratio of Nd^3 to the size range Δd. This type of presentation tends to normalize the effect of bin width on bin population. This column shows a definite peak at 8μ for sample S2-PC-22 but no definite peaks for sample 305-AO-1.

TABLE 5

Particle Frequency-Size and Mass-Size Distributions
in the Pan Fraction of Sample S2-PC-22

Size Range Δd (μ)	Number of Particles N	Nd^3 (μ^3)[a]	$Nd^3/\Delta d$ (μ^2)
0- 0.343	8,140	41	120
0.343- 0.686	304	41	120
0.686- 1.029	74	47	137
1.029- 1.370	25	43	126
1.370- 2.40	24	160	155
2.40 - 3.77	24	720	526
3.77 - 5.83	12	1,300	631
5.83 - 7.55	27	8,100	4,700
7.55 - 9.26	29	24,000	14,000
9.26 - 11.32	11	11,000	5,000
11.32 - 17.15	10	28,700	4,210
17.15 - 20.58	3	17,400	5,070

[a] d is the midpoint diameter of the size range.
Nd^3 is proportional to the volume and approximately equal to the weight of the examined portion of the fraction in picograms.

TABLE 6

Particle Frequency-Size and Mass-Size Distributions
in the Pan Fraction of Sample 305-AO-1

Size Range Δd (μ)	Number of Particles N	Nd^3 (μ^3)[a]	$Nd^3/\Delta d$ (μ^2)
0- 0.343	2,765	14	41
0.343- 0.686	73	10	29
0.686- 1.029	54	34	99
1.029- 1.370	9	16	47
1.370- 2.40	6	40	39
2.40 - 3.43	9	220	213
3.43 - 6.86	4	544	159
6.86 - 11.32	2	1,500	336
11.32 - 13.72	1	1,530	637
13.72 - 34.64	1	14,100	673
34.64 - 38.00	2	96,000	28,600

[a] d is the midpoint diameter of the size range.
Nd^3 is proportional to the volume and approximately equal to the weight of the examined portion of the fraction in picograms.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study clearly indicate the sample bias that can be introduced by mechanically shaking fallout samples. Only 10 minutes of shaking is sufficient to reduce the mass of large size fractions by 20 % and the gamma-ray activity of these fractions by 30 per cent. Pan fractions (<44 μ) can gain in weight by as much as 79 % and in activity by as much as 44 %. For predictions of fallout patterns in particular situations, perturbations of this magnitude are not serious in comparison with other uncertainties in meteorological conditions and sample reproducibility. However, they are sufficient to mislead investigators studying the partition of debris between local and worldwide fallout and the problem of dust loading. Therefore, mechanical shaking is unsuitable for the acquisition of data which will be applicable to studies of this type.

The unbiased pan fraction data for the 13,300-ft sample indicates a gradual tailing off of mass with decreasing particle size. No evidence of a second, small size peak in the mass-size distribution of this sample was observed. The 9,200-ft sample, however, shows a definite peak at 8 μ, which may correspond to the original lake-bed material. This indicates the possibility that such material was blown into the sample by the blast.

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3. Debris
4. Particle size
5. Sampling

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